CHASE ECONOMETRICS

THE ECONOMIC IMPACT OF NASA R&D SPENDING

UPDATE

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CONTRACT NUMBER: NASW-3346

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H 1980

U.S. ECONOMICS

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REPORT SUMMARY

OBJECTIVES

The objectives of this update to the 1976 Chase Econometrics study on the Economic Impact of NASA Research and Development Expenditures are:

- **Phase I**
  Using methodology employed in the 1976 study, to estimate an historical time series for γ, the rate of technological change in the U.S. economy.

- **Phase II**
  To reestimate an econometric equation to forecast γ, structurally similar to the equation estimated in the original study.

- **Phase III**
  To reestimate the equation "preferred" by the GAO in its critique of October 18, 1977.

- **Phase IV**
  Using the forecasting equation chosen by NASA from Phase II or Phase III, to simulate the Chase Econometrics Macroeconomic Model in order to calculate the secondary effects of NASA R&D expenditures on the economy.

- **Phase V**
  To calculate a rate of return from NASA R&D expenditures on real Gross National Product.

RESULTS

This preliminary report documents the approach used and degree of success in fulfilling the stated objectives.

(1) Because of data revisions and unclear and incomplete documentation of methodology, it is impossible to recreate with precision the historical time series for γ used in the 1976 study.

In the original study, γ was calculated as the residual of a Cobb-Douglas production function

$$\frac{\Delta X}{X} = \alpha \frac{\Delta L}{L} + (1 - \alpha) \frac{\Delta K}{K} + \gamma$$

where:
X = maximum potential GNP (CEA Trend Series)
L = maximum available labor force
R = maximum available capital put-in-place
α = 2/3 (estimated from factor share data)
γ = rate of technological change

There are two major problems in reestimating this residual:

- the CEA trend series for maximum potential GNP has been revised downward.
- the methodology employed in the 1976 study to estimate the rate of hidden unemployment (essential to the estimation of the maximum available labor force) was insufficiently documented to guarantee that we have precisely replicated the historical series.

(2) The econometric equations developed using a new time series for γ provide reasonably good historical fits but suffer from two faults.

First, the capacity utilization term overwhelms the specification, and second, the other terms, particularly NASA spending as a proportion of real GNP, are either statistically insignificant or have intuitively unreasonable signs. Overall, the equations were extremely unstable, as reflected in successive estimation over different time ranges. This instability was also noted in the GAO critique.

The results of the equation estimation phase can be seen in Equation 10 shown below. (This equation was taken from page 40 of the text.)

<u>Equation 10</u>

GAMM1	= 0.115 +	0.004 * NRD +	0.029 *ORD -		
	(0.22)	(0.06)	(1.14)		
	0.001 * (IMTOTAL - IMAVG)			-0.136 * (CP - CPAVG)	
	(-1.97)			(-4.62)	

NOB	= 23 NOVAR = 5
RANGE	= 56 to 78
RSQ	= 0.835 CRSQ = 0.798 F(4/18) = 22.788
SER	= 0.3630 SSR = 2.372 DW(0) = 2.07
PCT SER	= 48.95 DEPENDENT MEAN = 0.74162

where

GAMM1	= γ Productivity Trend
NRD	= Constant Dollar NASA R&D Expenditures as a proportion of real GNP, using lag structure from Exhibit 17.
ORD	= Other Constant Dollar R&D Expenditures as a proportion of real GNP, using capacity utilization ratio.
IMTOTAL	= Industry mix variable.
IMAVG	= Mean of industry mix variable over range of estimation.
CP	= Capacity utilization.
CPAVG	= Mean of capacity utilization over range of estimation.

Both the NASA R&D term and the other R&D terms are not statistically significant. In addition the industry mix variable has an intuitive unreasonable sign. An

Equation 11, (taken from page 40 of the text) estimated in the 1976 study, is displayed for comparison. It is difficult to determine whether the deterioration in the specification has resulted from the broader range of estimation (1956 to 1978 as compared with 1960 to 1974), historical data revisions, or the insufficient documentation of the methodology employed in the 1976 study.

Equation 11

$$\underset{}{\gamma} = -1.81 + \underset{(3.9)}{0.426\ NRD} + \underset{(2.0)}{0.474\ ORD}$$

$$+ \underset{(4.1)}{0.031\ (IM\text{-}IMAVG)} - \underset{(3.1)}{0.157\ (CP\text{-}CPAVG)}$$

R^2 = 0.883
DW = 1.95
Sample Period = 1960-1974

(3) These problems caused further work to be stopped.

Because we were unable to develop an equation for γ without a major new study (which would involve reopening most of the issues raised in the initial study), NASA and Chase Econometrics decided not to proceed with Phase III, Phase IV, or Phase V.

CONCLUSIONS

The problems encountered in trying to replicate the prior study with an expanded time series calls into serious question the soundness of results obtainable from this sort of "macro" level approach to the estimation of returns to NASA R&D expenditures. While it is possible that some of these difficulties could be overcome if more time and effort were devoted to the task, there are conceptual simplifications implicit in the aggregate approach that will not disappear with more work.

- The relationship between aggregate U.S. technological change and NASA-induced technological change is largely speculative. Separating the effects of NASA R&D from other R&D requires more analysis of specific instances because of the high level of collinearity involved in aggregate analysis.

- The aggregate impact is merely an **average** impact, which masks the differences in impact among the various sectors of the economy. These differences and their causes are more important than the average of growing, slowing, and stagnant sectors. The role of NASA expenditures in stimulating or sustaining demand for newly emerging technologies, for example, goes unrecognized in the aggregate analysis.

Our experience and that of other investigators in this general area suggests that further attention should be focused in the future on the examination of effects at a more micro level. Two avenues of analysis suggest themselves at this point and would be mutually complementary:

- **Selected industry case studies** would look in depth at the effect that NASA expenditures have had in creating or sustaining demand or stimulating technological break-throughs. Areas such as instrumentation, microelectronics, communications, and specialty materials might yield particularly valuable insights on the role of NASA in stimulating innovation and economic growth.

- **Interindustry studies** would provide a basis for aggregating effects determined in the study of selected industries and for evaluating second order effects. Use of large interindustry models, such as the 200-sector University of Maryland model (INFORUM) which can reflect interindustry substitution effects, industry-specific price and investment effects, etc., should provide significant new insights.

The chapters which follow describe in further detail the specific results obtained and the problems encountered in carrying out Phases I and II of this study.

PHASE I

ESTIMATING AN HISTORICAL TIME SERIES FOR γ

The objective in Phase I of this update study was to develop an historical time series for γ, or the rate of technological change, with a range of 1956 to 1978. The 1976 study used a Cobb-Douglas production function with constant returns to scale to calculate a residual (γ) from the following differential equation:

$$\frac{\Delta X}{X} = \alpha \frac{\Delta L}{L} + (1 - \alpha) \frac{\Delta K}{K} + \gamma$$

where: X = maximum potential GNP (CEA Trend Series)
L = maximum available labor force
K = maximum available capital put-in-place
α= 2/3 (estimated from factor share data)
γ= rate of technological change

Adding three additional data points (1976-1978) to the historical time series for γ involved considerably greater effort than anticipated because of four unexpected problems that were encountered:

- Revisions in basic data.
- Replication of key parameters in estimation of maximum available labor force.
- Estimation of capital stock.
- Interpretation of prior definitions.

A. REVISIONS IN BASIC DATA

The 1976 study used the CEA trend estimate of maximum potential GNP (X), which has since been revised downward; the largest revisions begin in 1967 (see Exhibit 1

Exhibit 1

Measurement of Potential GNP
CEA Trend Method

	% Change, Revised Series	% Change, 1976 Study	Difference
1954	3.5	3.5	0.0
1955	3.4	3.5	-0.1
1956	3.5	3.5	0.0
1957	3.5	3.5	0.0
1958	3.5	3.5	0.0
1959	3.5	3.5	0.0
1960	3.4	3.5	-0.1
1961	3.5	3.5	0.0
1962	3.5	3.5	0.0
1963	3.7	3.6	0.1
1964	3.9	3.7	0.2
1965	3.9	3.8	0.1
1966	3.9	3.9	0.0
1967	3.7	4.0	-0.3
1968	3.6	4.0	-0.4
1969	3.5	4.0	-0.5
1970	3.5	4.0	-0.5
1971	3.6	4.0	-0.4
1972	3.5	4.0	-0.5
1973	3.0	4.0	-1.0
1974	3.0	4.0	-1.0
1975	3.0	NA	NA
1976	3.0	NA	NA
1977	3.0	NA	NA
1978	3.0	NA	NA

on page 8). Obviously, as a result, the γ residual would also change in the critical 1967-1974 period.

B. REPLICATION OF KEY PARAMETERS

Even greater difficulties arose in duplicating estimates presented in the 1976 study. The previous study defined L as follows:

$$L = \frac{E}{\left(1 - \frac{UN}{100} - \frac{UN_H}{100}\right)} * h_{max}$$

E = total employment, including self-employed and agricultural workers.

h_{max} = index of maximum hours worked per week.

UN = rate of unemployment, %.

UN_H = rate of hidden unemployment, %.

$$UN_H = \sum_{i=1}^{4} \left\{ \left[[\alpha + \beta t]_i - \left(\frac{LF}{POP}\right)_i \right] * \left(\frac{LF_i}{LF}\right) \right\} * 100\%$$

where:

$\alpha + \beta t$ is a trend line through peak points of labor force by each age-sex classification. As t increases, the value of the expression $\alpha + \beta t$ also increases, indicating that labor force participation rates increase over time.

LF_i = labor force by age-sex classification.

POP_i = population by age-sex classification.

i = 1, ..., 4; groups are males aged 16-24
females aged 16-24
females aged 25-54
total aged over 55

No secondary workers in males aged 25-54 were assumed.

The specific problems that arose in replicating this estimation are described further in the next several pages:

1. **Maximum Hours Worked**

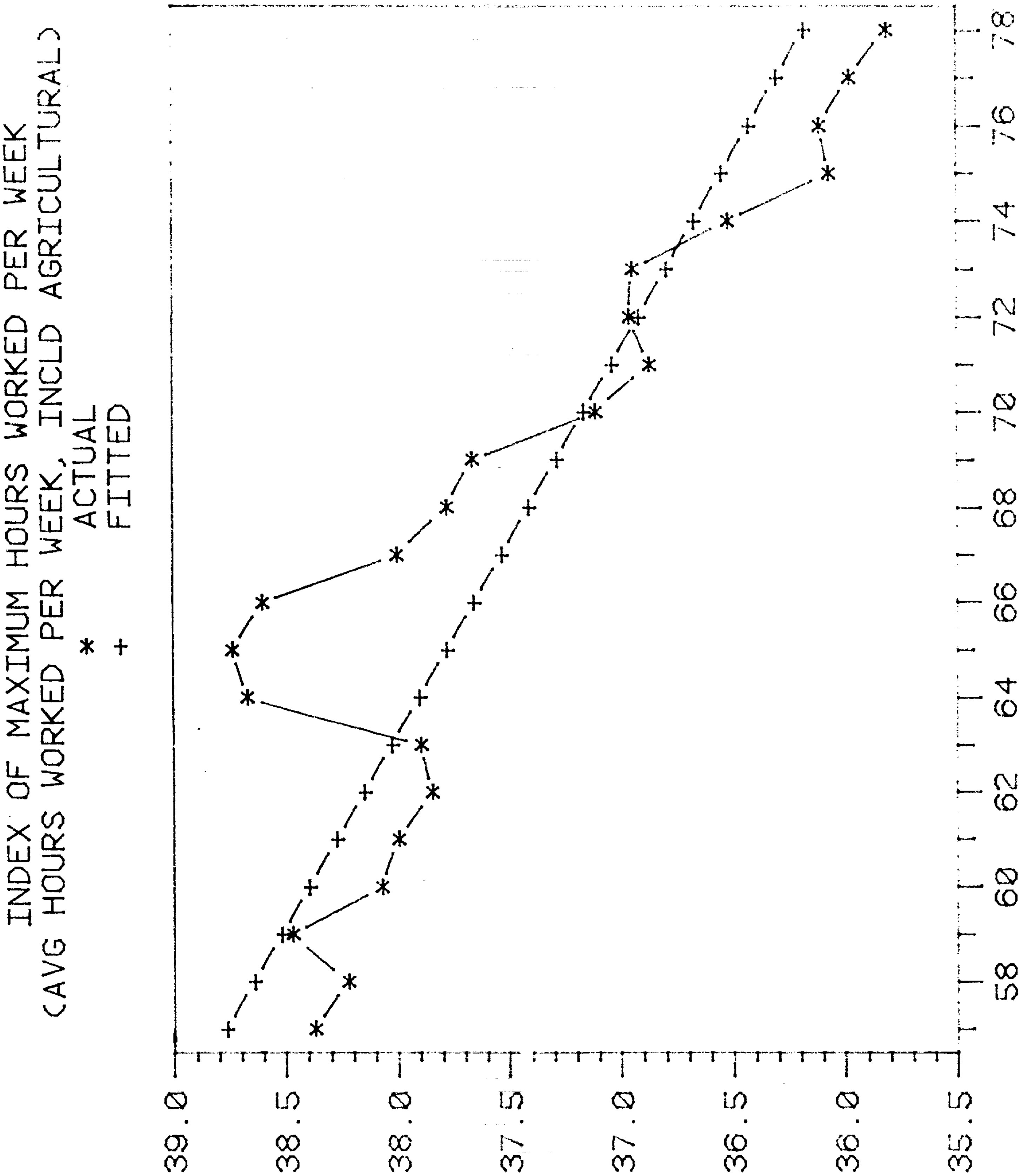
We have not been able to locate the time series "h_{max} = index of maximum hours worked per week." What we used is a time series measuring average hours worked per week, including the agricultural sector. To remove the cyclicality of the series, we estimated an ordinary least squares trend line, and used the fitted values as the time series measuring hours worked per week. Since the 1976 study apparently used an index number, we converted this series to an index number with 1956 = 1.0, although this last step was not necessary since $\frac{\Delta L}{L}$ would be the same in either case. We have also assumed that this term was included to incorporate the impact of the secular decline in average weekly hours on quantity of labor available (see Equation 1, Exhibit 2, and Exhibit 3).

<u>Equation 1</u>

Average Hours Worked Per Week Regressed Against Time

HRSTPA	=	39.9527 - 0.03078 * T
NOB	=	26 NOVAR = 2
RANGE	=	53 to 78
RSQ	=	0.840 CRSQ = 0.833 F(1/24) = 1.E+02
SER	=	0.4193 SSR = 4.219 DW(0) = 0.46
PCT SER	=	1.11 DEPENDENT MEAN = 37.72140

Exhibit 2



INDEX OF MAXIMUM HOURS WORKED PER WEEK
(AVG HOURS WORKED PER WEEK, INCLD AGRICULTURAL)
* ACTUAL
+ FITTED
39.0
38.5
38.0
37.5
37.0
36.5
36.0
35.5
58
60
62
64
66
68
70
72
74
76
78

Exhibit 3

Index of "Maximum Hours Worked Per Week"
(Average Hours Worked Per Week,
Including Agricultural)

	Actual Series	Fitted Values (39.953–0.03 *Actual)	Index (1956=1.0 Based on Fitted Values)
1953	39.100	39.260	1.009
1954	39.000	39.137	1.006
1955	39.000	39.014	1.003
1956	38.850	38.891	1.000
1957	38.375	38.768	0.997
1958	38.225	38.645	0.994
1959	38.475	38.522	0.991
1960	38.075	38.399	0.987
1961	38.000	38.275	0.984
1962	37.850	38.152	0.981
1963	37.900	38.029	0.978
1964	38.675	37.906	0.975
1965	38.742	37.783	0.972
1966	38.608	37.660	0.968
1967	38.008	37.537	0.965
1968	37.783	37.414	0.962
1969	37.667	37.291	0.959
1970	37.117	37.168	0.956
1971	36.875	37.044	0.953
1972	36.967	36.921	0.949
1973	36.950	36.798	0.946
1974	36.525	36.675	0.943
1975	36.075	36.552	0.940
1976	36.117	36.429	0.937
1977	35.983	36.306	0.934
1978	35.817	36.183	0.930

where:

HRSTPA = Hours worked per week, total.
T = Time Trend

2. Hidden Unemployment

The second problem encountered in estimating the labor factor in the Cobb-Douglas function involved the use of a "hidden unemployment" term. An ideal measurement of hidden unemployment should account for three separate deficiencies in the reported unemployment rate.

- The "discouraged worker syndrome" or those individuals who are no longer actively seeking employment because of diminishing job opportunities, usually a cyclical phenomenon.
- The secular decline in the number of self-employed; the 1976 study stated that "as the percentage of these workers in the labor force increases, a constant unemployment rate indicates a declining labor reserve measured in terms of effective labor input." This secular decline also implies a decline in the hidden unemployment rate.
- The secular decline in the number of secondary workers or the "reserve labor pool," which would also imply a declining rate of hidden unemployment.

Because of the methodology employed, we do not believe any of these deficiencies were accounted for in the 1976 study. The estimation of UN_H was performed as follows:

$$UN_H = \sum_{i=1}^{4} \left\{ \left[\left[\alpha + \beta t\right]_i - \left(\frac{LF}{POP}\right)_i \right] * \left(\frac{LF_i}{LF_{TOT}}\right) \right\} * 100\%$$

$\alpha + \beta t$ was defined as a trend line through peak points of labor force participation rates by each age - sex classification; additionally, "an increase in the value of the expression $\alpha + \beta t$ indicates that labor force participation rates increase over time." (p. 44, 1976 study).

Presumably, this trend line approach would eliminate cyclicality in labor force participation rates, thus overcoming the "discouraged worker" deficiency mentioned above and adjust for secular changes in labor force participation rates. It is impossible, however, to satisfactorily identify those peaks in labor force participation rates by the four age-sex classifications. In addition, although it is true in the aggregate, labor force participation rates for the last category (total aged over 55) do not increase over time but exhibit a declining secular trend. Labor force participation rates for category 1, males aged 16-24, decline through the 1960s and only then exhibit an increasing trend (see Exhibits 4 to 8).

We first attempted to identify peak points in participation rates by inspection. For category 1, we selected five peaks; for category 2, four peaks were chosen and four peaks were isolated in category 4. No "peaks" were discernible in category 3; consequently, we selected those observations where the percentage change in labor force participation rates was largest from year to year. This problem is illustrated in Exhibits 5-8, and the results of our initial peak-year decision in Exhibit 9. Estimated equations are Equations 2 to 5.

Exhibit 4

Labor Force Participation Rates

	Males 16-24	Females 16-24	Females 25-54	Total Over 55
1948	.76	.44	.35	.43
1949	.77	.44	.36	.43
1950	.77	.44	.37	.43
1951	.77	.45	.38	.43
1952	.75	.44	.38	.42
1953	.74	.43	.38	.42
1954	.72	.43	.39	.42
1955	.72	.43	.40	.42
1956	.74	.44	.41	.43
1957	.73	.44	.42	.42
1958	.72	.43	.42	.41
1959	.72	.42	.42	.41
1960	.72	.43	.43	.41
1961	.71	.43	.43	.41
1962	.70	.43	.43	.40
1963	.69	.43	.44	.39
1964	.69	.43	.45	.40
1965	.69	.44	.45	.39
1966	.69	.46	.46	.39
1967	.69	.48	.47	.39
1968	.68	.49	.48	.39
1969	.69	.50	.49	.39
1970	.70	.51	.50	.39
1971	.70	.51	.50	.38
1972	.71	.53	.51	.37
1973	.73	.55	.52	.36
1974	.74	.57	.54	.35
1975	.72	.57	.55	.35
1976	.73	.58	.57	.34
1977	.74	.60	.58	.34
1978	.75	.62	.61	.34

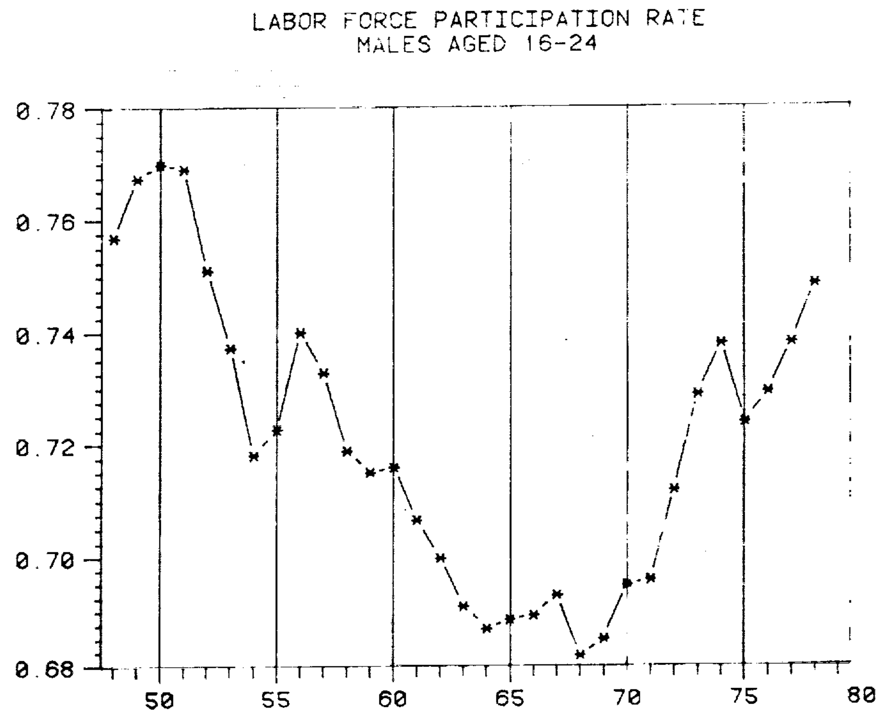


Exhibit 5

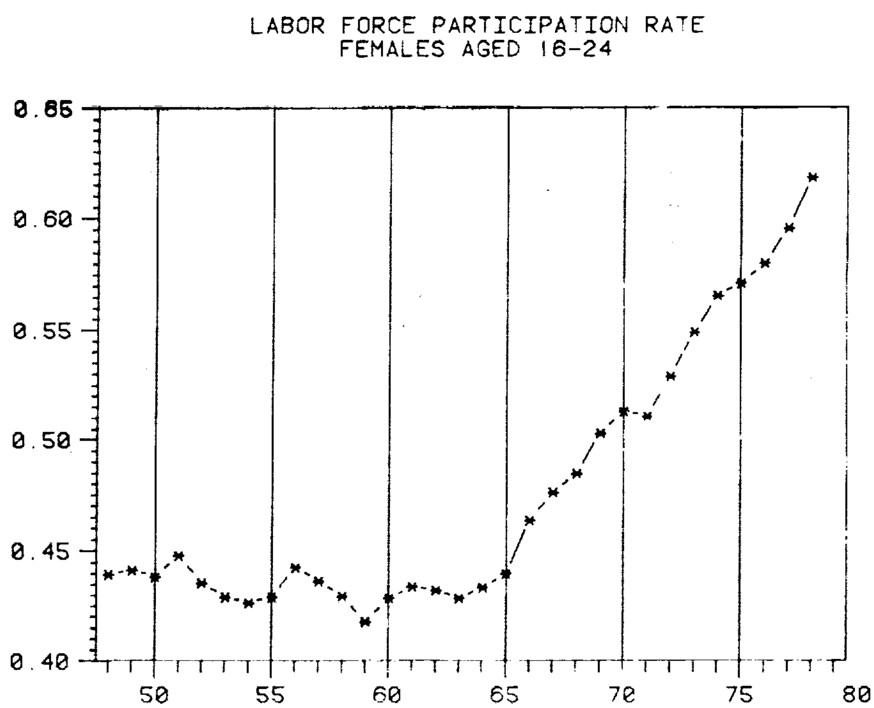


Exhibit 6

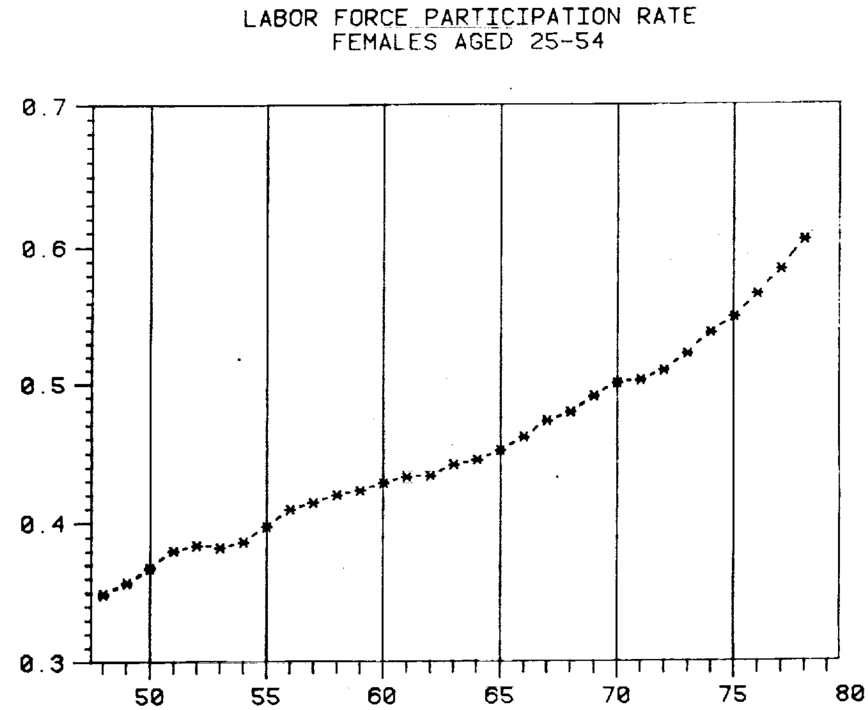


Exhibit 7

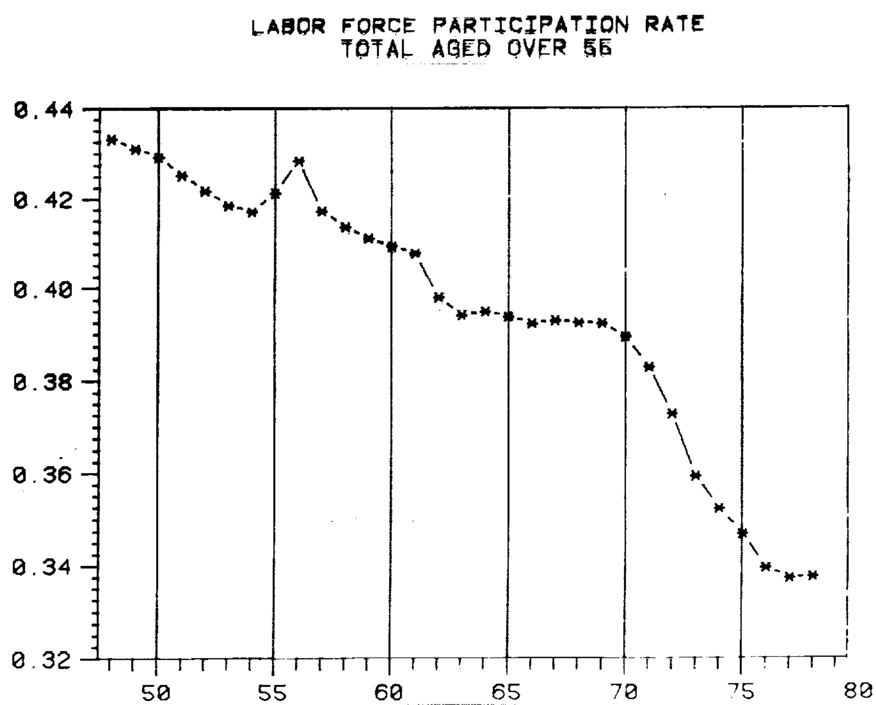


Exhibit 8

Equation 2

PEAK1	=	0.74773 - 0.00383 * T
		(27.88) (-0.56)**
NOB	=	6 NOVAR = 2
RANGE	=	1 to 6
RSQ	=	0.072 CRSQ = -0.160 F(1/4) = 0.309
SER	=	0.0288 SSR = 3.321E-03 DW(0) = 1.22
PCT SER	=	3.92 DEPENDENT MEAN = 0.73433

where:

PEAK1	=	Peak values for labor force participation rate, males 16-24.
T	=	Time series for NASA equations, labor force rates.

Equation 3

PEAK2	=	0.351 + 0.0604 * T
		(6.91) (3.26)
NOB	=	4 NOVAR = 2
RANGE	=	1 to 4
RSQ	=	0.841 CRSQ = 0.762 F(1/2) = 10.601
SER	=	0.415 SSR = 3.441E-03 DW(0) = 2.08
PCT SER	=	8.26 DEPENDENT MEAN = 0.50200

where:

PEAK2	=	Peak period labor force participation rates, females 25-54.
T	=	Time series for NASA equations, labor force rates.

Equation 4

```
PEAK3    = 0.35964 + 0.02586 * T
           (19.12)   (6.94)

NOB      = 8   NOVAR = 2
RANGE    = 1 to 8
RSQ      = 0.889   CRSQ = 0.871   F(1/6) = 48.205
SER      = 0.0241   SSR = 3.495E-03   DW(0) = 0.84
PCT SER  = 5.07   DEPENDENT MEAN = 0.47600
```

where:
PEAK3 = Peak period labor force participation rates, females 25-54.
T = Time series for NASA equations, labor force rates.

Equation 5

```
PEAK4    = 0.4448 - 0.0184 * T
           (24.74)  (-3.39)

NOB      = 5   NOVAR = 2
RANGE    = 1 to 5
RSQ      = 0.793   CRSQ = 0.725   F(1/3) = 11.521
SER      = 0.0171   SSR = 8.816E-04   DW(0) = 2.48
PCT SER  = 4.40   DEPENDENT MEAN = 0.38960
```

where:
PEAK4 = Peak labor force participation rates, total population over 55.
T = Time series for NASA equations, labor force rates.

**Numbers in parentheses represent t-statistics.

Exhibit 9

Labor Force Participation Rates, Peak Years

	Males 16-24	Females 16-24	Females 25-54	Total Over 55
1956	.74	.44	.41	.43
1957				
1958			.42	
1959				
1960	.72		.43	
1961		.43		
1962				
1963			.44	
1964				.40
1965				
1966				
1967	.69		.47	.39
1968				.39
1969			.49	
1970		.51		
1971				
1972				
1973				
1974	.74		.54	
1975				
1976				
1977				
1978	.75	.62	.61	

This approach, however, resulted in a severe overcorrection for cyclicality in participation rates and absurdly high hidden unemployment rates. We then decided to abandon our efforts to identify peaks in participation rates, and, using the unemployment rate, identified eight peak years, i.e., full employment years in the economy. Then, using the labor force participation rates for each classification in those peak years, we estimated trend lines with the interpolated time trend shown in Exhibit 10.

Exhibit 10
Participation Rates in Peak Years

	Unemployment Rate	Time Trend	Males 16-24	Females 16-24	Females 25-54	Total Over 55
1950	5.21	0.25				
1951	3.28	0.50				
1952	3.03	0.75				
1953	2.95 PEAK	1.00	0.74	0.43	0.38	0.42
1954	5.59	1.33				
1955	4.37	1.67				
1956	4.13 PEAK	2.00	0.74	0.44	0.41	0.43
1957	4.30	2.33				
1958	6.84	2.67				
1959	5.45 PEAK	3.00	0.72	0.42	0.42	0.41
1960	5.54	3.33				
1961	6.69	3.67				
1962	5.57 PEAK	4.00	0.70	0.43	0.43	0.41
1963	5.64	4.25				
1964	5.16	4.50				
1965	4.51	4.75				
1966	3.79 PEAK	5.00	0.69	0.46	0.46	0.39
1967	3.84	5.33				
1968	3.56	5.67				
1969	3.49 PEAK	6.00	0.69	0.50	0.49	0.39
1970	4.98	6.25				
1971	5.95	6.50				
1972	5.58	6.75				
1973	4.85 PEAK	7.00	0.73	0.55	0.52	0.36
1974	5.58	7.20				
1975	8.47	7.40				
1976	7.68	7.60				
1977	7.03	7.80				

For each set of peak points we then estimated an OLS equation using time as the independent variable. The results are shown in Equations 6-9.

Equation 6

PEAK1	=	0.72429 - 0.00095 * TIME
		(36.17) (-0.24)
NOB	=	8 NOVAR = 2
RANGE	=	1 to 8
RSQ	=	0.010 CRSQ = -0.156 F(1/6) = 0.058
SER	=	0.0257 SSR = 3.962E-03 DW(0) = 0.74
PCT SER	=	3.57 DEPENDENT MEAN = 0.72000

where:

PEAK1 = Values of labor force participation rates, males 16-24 in full employment economy.

TIME = Time trend for full employment peaks.

Equation 7

PEAK2	=	0.36607 + 0.02560 * TIME
		(12.89) (4.55)
NOB	=	8 NOVAR = 2
RANGE	=	1 to 8
RSQ	=	0.775 CRSQ = 0.738 F(1/6) = 20.707
SER	=	0.0365 SSR = 7.973E-03 DW(0) = 0.67
PCT SER	=	7.57 DEPENDENT MEAN = 0.48125

where:

PEAK2 = Values of labor force participation rates, females 16-24 in full employment economy.

TIME = Time trend for full employment peaks.

Equation 8

```
PEAK3    = 0.33643 + 0.02857 * TIME
           (16.90)   (7.25)

NOB      = 8   NOVAR = 2
RANGE    = 1 to 8
RSQ      = 0.898   CRSQ = 0.880   F(1/6) = 52.555
SER      = 0.0255   SSR = 3.914E-03   DW(0) = 1.14
PCT SER  = 5.49   DEPENDENT MEAN = 0.46500
```

where:

PEAK3 = Values of labor force participation rates, females 25-54, in years of full employment.

TIME = Time trend for full employment peaks.

Equation 9

```
PEAK4    = 0.44679 - 0.01179 * TIME
           (51.16)   (-6.82)

NOB      = 8   NOVAR = 2
RANGE    = 1 to 8
RSQ      = 0.886   CRSQ = 0.867   F(1/6) = 46.450
SER      = 0.0112   SSR = 7.536E-04   DW(0) = 1.71
PCT SER  = 2.85   DEPENDENT MEAN = 0.39375
```

where:

PEAK4 = Values of labor force participation rates, total over 55, in years of full employment.

TIME = Time trend for full employment peaks.

Using these estimated time trends as the $\alpha + \beta t$ term also results in an overcorrection for the discouraged worker phenomenon, but at a more acceptable level. In any case, contrary to accepted theory, and contrary to the 1976 report which implied that this methodology would measure a secularly declining hidden unemployment rate, the hidden unemployment term actually increases over time, as shown below. Time constraints and the scope of this project precluded our using an alternative methodology to measure hidden unemployment. Consequently, we have decided to use the hidden unemployment rate calculated by the full employment methodology (see Exhibit 11). Using this measure of hidden unemployment, the reported unemployment rate, and our index of maximum hours worked, we then calculated the maximum effective labor force variable (Exhibit 12). The results are shown:

<u>Maximum available labor force</u>

$$L = \frac{E}{\left(1 - \frac{UN}{100} - \frac{UN_H}{100}\right)} * h_{max}$$

where:

L	=maximum labor force
E	=total employment, including agricultural
UN	=reported unemployment rate
UN_H	=hidden unemployment
h_{max}=	index of maximum hours worked per week

Exhibit 11

Hidden Unemployment (%)

	Original Methodology	Full Employment Methodology
1956	-0.7	0.5
1957	0.5	0.7
1958	1.6	1.0
1959	2.6	1.3
1960	3.5	1.4
1961	4.6	1.6
1962	5.8	2.1
1963	7.0	2.4
1964	8.0	2.6
1965	9.1	2.6
1966	10.1	2.5
1967	11.1	2.4
1968	12.4	2.6
1969	13.5	2.4
1970	14.6	2.6
1971	16.1	3.3
1972	17.5	3.5
1973	19.0	3.5
1974	20.5	3.5
1975	22.3	3.8
1976	23.9	3.8
1977	25.3	3.7
1978	26.5	3.7

Exhibit 12

	Maximum Labor Force	Percent Change
1956	54.88	3.05
1957	55.44	1.01
1958	55.31	-0.24
1959	56.56	2.27
1960	57.46	1.60
1961	57.95	0.84
1962	59.01	1.83
1963	60.22	2.05
1964	61.55	2.21
1965	63.57	3.28
1966	66.03	3.88
1967	67.72	2.55
1968	69.56	2.71
1969	71.67	3.03
1970	73.29	2.27
1971	74.72	1.95
1972	76.91	2.93
1973	79.29	3.10
1974	81.22	2.44
1975	82.44	1.49
1976	83.98	1.88
1977	86.14	2.57
1978	89.08	3.41

C. ESTIMATION OF CAPITAL STOCK

The third and least of the problems in recreating an historical time series for γ concerns estimation of the stock of capital term. The 1976 study used a thirty year lag in order to develop a measure of the stock of residential structures. Since it was necessary to estimate an observation for 1956 (actually a change from 1955), we required data on investment in residential structures back to 1925. NIPA accounts, however, begin in 1929. Consequently, it was necessary to extrapolate the time series on investment in residential structures backwards; we believe this was also done in the original study. There were no other significant problems in estimating the K term. We did find it peculiar, however, that the author made no mention of the fact that the investment series for nonresidential structures and producers durable equipment do not entirely reflect investment in productive assets; both series include nonproductive investment required to meet EPA and OSHA mandates, as well as energy efficiency standards. The CEA also does not adjust for that type of investment in estimating its potential GNP trend series; consequently, it might be expected that both the CEA and capital stock series are overstated. Our suggestion would be to reestimate both series, adjusting for nonproductive investment. Nevertheless, in order to approximate the previous study, we chose to ignore the issue, although there may be less understatement of the effectiveness of capital stock using this methodology than the 1976 study claimed.

In short, K is calculated as follows:

$$K = \sum_{i=0}^{15} \lambda_1^{\,i} (I_{pe})_{-i} + \sum_{i=0}^{20} \lambda_2^{\,i} (I_{ps})_{-i} + \sum_{i=0}^{30} \lambda_3^{\,i} (I_h)_{-i} + \sum_{i=0}^{20} \lambda_4^{\,i} (I_{gs})_{-i}$$

where:

I_{pe} = purchases of producers durable equipment, constant \$
I_{ps} = purchases of nonresidential structures, private sector, constant \$
I_h = purchases of residential structures, private sector, constant \$
I_{gs} = purchases of nonresidential structures, public sector, constant \$

The λ_j are determined so that each $\lambda^N = 0.05$, representing the approximate scrappage value in each case. Results are shown in Exhibit 13.

Exhibit 13

Total Stock of Capital
Billions of Constant $

	Producers Durable Equipment	Private Non-residential Structures	Private Residential Structures	Public Non-Residential Structures	Total Stock
1955	162.502	129.508	210.582	88.449	591.041
1956	169.507	139.364	221.992	93.232	624.094
1957	175.933	147.758	230.098	97.904	651.693
1958	176.150	153.181	238.263	103.846	671.438
1959	179.989	158.319	253.107	109.307	700.721
1960	184.111	164.725	263.385	114.248	726.469
1961	186.276	170.709	273.091	120.014	750.090
1962	191.676	177.275	285.171	125.252	779.373
1963	198.385	183.151	301.157	131.772	814.466
1964	208.822	190.843	316.210	138.512	854.386
1965	225.869	203.658	329.183	145.724	904.434
1966	247.286	217.445	336.176	153.157	954.064
1967	263.605	227.462	341.111	159.882	992.059
1968	280.654	237.026	351.145	166.847	1035.670
1969	298.749	247.262	360.646	170.106	1076.760
1970	310.594	254.924	366.241	170.029	1101.790
1971	319.203	260.364	383.040	169.440	1132.050
1972	334.181	265.783	408.037	168.024	1176.020
1973	357.675	273.373	428.631	167.134	1226.810
1974	379.665	276.927	432.720	166.690	1256.000
1975	385.955	274.490	430.218	165.096	1255.760
1976	395.240	273.567	436.960	161.789	1267.560
1977	412.316	273.426	452.384	156.784	1294.910
1978	432.226	278.104	468.557	154.573	1333.460

D. INTERPRETATION OF PRIOR DEFINITIONS

Finally, there was a minor problem interpreting the meaning of

$$\frac{\Delta X}{X}, \frac{\Delta L}{L}, \text{ and } \frac{\Delta K}{K}.$$

We assumed these terms would normally not be calculated as percent changes, which are defined as

$$\frac{X_t - X_{t-1}}{X_{t-1}}, \quad \frac{L_t - L_{t-1}}{L_{t-1}}, \quad \text{and} \quad \frac{K_t - K_{t-1}}{K_{t-1}} \quad \text{or} \quad \frac{\Delta X}{X_{t-1}}, \quad \frac{\Delta L}{L_{t-1}}, \quad \text{and} \quad \frac{\Delta K}{K_{t-1}}$$

However, the original text explicitly used percent change in potential GNP to measure $\frac{\Delta X}{X}$, not the first derivative. In any case, we calculated two alternative versions of γ; the first is based on percent change and is referred to in the equations as GAMM1; the second uses the first derivative to calculate rate of change for each of the terms and is defined as GAMM2. Exhibit 14 displays the percent change in each term, as well as both estimates of γ. As will be seen later in the analysis of Phase II, there is no significant difference in the estimation process. Consequently, since we believe the percent change form was used in the original study, we used GAMM1.

Exhibit 14

Calculation of γ

$$\gamma = \frac{\Delta X}{X} - 2/3 \frac{\Delta L}{L} - 1/3 \frac{\Delta K}{K}$$

	% Change Potential GNP	% Change Labor Force	% Change Capital Stock	% Change GAMM1	First Derivative GAMM2
1956	3.454	3.055	5.592	-0.447	-0.288
1957	3.457	1.010	4.422	1.310	1.380
1958	3.457	-0.235	3.030	2.603	2.633
1959	3.452	2.267	4.361	0.487	0.581
1960	3.444	1.600	3.674	1.153	1.213
1961	3.459	0.841	3.251	1.815	1.853
1962	3.481	1.829	3.904	0.961	1.031
1963	3.715	2.053	4.503	0.845	0.937
1964	3.874	2.207	4.901	0.768	0.877
1965	3.898	3.280	5.858	-0.242	-0.064
1966	3.870	3.882	5.487	-0.547	-0.355
1967	3.695	2.553	3.982	0.665	0.759
1968	3.553	2.713	4.396	0.279	0.389
1969	3.548	3.031	3.968	0.204	0.314
1970	3.548	2.271	2.324	1.259	1.310
1971	3.553	1.945	2.746	1.340	1.390
1972	3.544	2.934	3.885	0.293	0.397
1973	3.448	3.095	4.319	-0.055	0.067
1974	3.032	2.437	2.379	0.614	0.671
1975	2.998	1.491	-0.019	2.010	2.025
1976	2.995	1.876	0.939	1.432	1.457
1977	3.005	2.570	2.158	0.572	0.630
1978	3.004	3.414	2.977	-0.264	-0.160

PHASE II

The Phase II activity is discussed in this chapter, with two principal parts to the discussion:

- Variable Selection and Estimation
- Equation Estimation

A. VARIABLE SELECTION AND ESTIMATION

Because the historical time series for γ estimated in Phase I was significantly different from that which was used in the 1976 study, we began Phase II with a serious unanticipated problem. The objective of this phase was the reestimation of a structural equation for γ similar to the equation estimated in 1976. The differences in the two historical time series, outlined in Exhibit 15, make difficult the task of differentiating between changes in the specification which are due to the addition of three extra data points and those attributable to the revisions in the historical data. Nevertheless, there are enough similarities in the time series to make possible a reestimation of the equation without any major respecification.

Three variables were ultimately selected as major determinants of γ in the 1976 study:

- **Research and Development Expenditures.** The theoretical reason for including this variable is to quantify the impact R&D expenditures have on productivity in the economy, with appropriate time lags. The hypothesis is that R&D expenditures result in a higher level of technology in a significant portion of the industrial sector, and that higher technology results in greater productivity.

- **An Industry Mix Variable.** A mix variable is used to account for any change in productivity which may be the result of a shift in the relative proportion of GNP of high and low technology (or high and low productivity) industries.

- **Capacity Utilization.** This variable, which was critical in the 1976 study, is included to account for the cyclical phenomenon in productivity, namely, that higher levels of capacity utilization yield diminishing returns to productivity.

Exhibit 15

Historical Time Series Used to Estimate γ Equation

	Current Study	1976 Study	Difference
1956	-0.447	-0.25	-0.197
1957	1.310	0.98	0.33
1958	2.603	2.81	-0.207
1959	0.487	1.73	-1.243
1960	1.153	1.54	-0.387
1961	1.815	2.19	-0.375
1962	0.961	1.48	-0.519
1963	0.845	1.58	-0.735
1964	0.768	1.04	-0.272
1965	-0.242	-0.05	-0.192
1966	-0.547	-1.42	0.873
1967	0.665	-0.19	0.855
1968	0.279	0.57	-0.291
1969	0.204	0.21	-0.006
1970	1.259	1.36	-0.101
1971	1.340	2.58	-1.24
1972	0.293	1.35	-1.057
1973	-0.055	0.68	-0.735
1974	0.614	1.10	-0.486
1975	2.010	NA	NA
1976	1.432	NA	NA
1977	0.572	NA	NA
1978	-0.264	NA	NA

Of course, several issues were raised in both the selection of these variables and the way in which they entered the Y equation. It is not the objective of this study, however, to critique the decision criteria used in variable selection, except where essential to the reestimation process.

1. **Research and Development Expenditures**

The original study disaggregated R&D expenditures into two types—NASA R&D expenditures and other R&D expenditures. The historical time series for the former was contributed by NASA and adjusted for fiscal-calendar year discrepancies by averaging successive years; appropriate adjustments were also made in the update study for the shift from July-July fiscal year to October-October fiscal year basis. The historical time series used to estimate other R&D expenditures comes from the National Science Foundation (total funds for performances of research and development minus NASA outlays for research and development). Both time series are in billions of 1972 dollars; the implicit GNP deflator is used to convert to constant dollars, with appropriate adjustment made for fiscal-calendar year discrepancies. The time series used are displayed in Exhibit 16. Additionally, in the absence of data, estimates of total R&D expenditures were used for observations made for the years from 1948 to 1953.

The basic problem involved in replicating the 1976 study with respect to the R&D terms involved the specification of the distributed lag structure. Software currently exists to permit

Exhibit 16

Research and Development Expenditures
(millions of dollars)

	Current $ NASA R&D Outlays Calendar Years	Current $ Total R&D Expenditures	Current $ Other R&D Expenditures	Implicit GNP Deflator	Constant $ NASA R&D Expenditures	Constant $ Other R&D Expenditures
1948	0.000	2000.000	2000.000	53.128	0.000	3764.530
1949	0.000	2200.000	2200.000	52.585	0.000	4183.700
1950	0.000	2500.000	2500.000	53.615	0.000	4662.870
1951	0.000	3500.000	3500.000	57.268	0.000	6111.670
1952	0.000	4500.000	4500.000	57.995	0.000	7759.290
1953	0.000	5128.000	5128.000	58.875	0.000	8709.980
1954	0.000	5651.000	5651.000	59.698	0.000	9466.050
1955	0.000	6182.000	6182.000	60.970	0.000	10139.400
1956	0.000	8375.000	8375.000	62.898	0.000	13315.300
1957	0.000	9791.000	9791.000	65.023	0.000	15057.900
1958	0.000	10734.000	10734.000	66.035	0.000	16255.000
1959	17.000	12384.000	12367.000	67.520	25.178	18316.100
1960	144.900	13551.000	13406.100	68.680	210.978	19519.700
1961	371.400	14346.000	13974.600	69.275	536.124	20172.600
1962	711.300	15426.000	14714.700	70.553	1008.190	20856.400
1963	1622.000	17093.000	15471.000	71.585	2265.840	21612.100
1964	2812.900	18894.000	16081.100	72.705	3868.920	22118.300
1965	3650.900	20091.000	16440.100	74.305	4913.390	22125.200
1966	4362.800	21894.000	17531.200	76.750	5684.430	22841.900
1967	4614.200	23205.000	18590.800	79.015	5839.650	23528.200
1968	4216.700	24669.000	20452.300	82.555	5107.740	24774.200
1969	3738.200	25686.000	21947.800	86.720	4310.650	25308.800
1970	3260.900	26047.000	22786.100	91.363	3569.190	24940.300
1971	2811.000	26745.000	23934.000	96.010	2927.820	24928.700
1972	2626.800	28415.000	25788.200	99.985	2627.190	25792.100
1973	2582.300	30417.000	27834.700	105.782	2441.140	26313.100
1974	2481.500	32322.000	29840.500	116.050	2138.300	25713.500
1975	2421.000	35196.000	32775.000	127.110	1904.650	25784.700
1976	2850.300	38581.000	35730.700	133.695	2131.940	26725.500
1977	2982.700	42702.000	39719.300	141.670	2105.380	28036.500
1978	3050.700	47000.000	43949.300	152.000	2007.040	28914.000

simultaneous estimation of lag weights and lag coefficients; in the 1976 study, weights were estimated first, and then applied to each R&D variable. The resulting weighted-average variable was then incorporated into a regression equation. The same proportional weights were used in the update study, as shown in Exhibit 17. Additionally, the R&D spending as a proportion of real Gross National Product, was incorporated into the equation shown in Exhibit 17.

Presumably, in order to improve the historical fit, the ORD term was multiplied by the ratio $\frac{1-CP}{1-\overline{CP}}$ where CP = capacity utilization, and $\overline{CP}$ = average capacity utilization over the estimation range. Theoretically, the greater the value of this ratio, the lower the historical level of capacity utilization will be, and hence R&D will have a greater incremental effect on productivity. The GAO study also noted that including this capacity utilization term had the desirable effect of inflating the coefficient of the NASA R&D term.

2. Industry Mix Term

The second term included in the final equation was an industry mix term. As stated before, the term is hypothetically used to account for a shift in the proportion of GNP represented by more highly productive industries. This term posed the most difficult problem in Phase II. Essentially, it does not represent what it is supposed to as structured in the 1976 study, i.e., it is improperly designed.

Exhibit 17

Distributed Lag Weights for R&D Spending

Time Lag (Years)	Proportional Weight (Average)
0	0.0
1	0.0
2	0.61
3	0.164
4	0.22
5	0.232
6	0.200
7	0.123
8 and later	0.0

$$\frac{\text{NASA R\&D Expenditures in Constant Dollars}}{\text{Real GNP}} = \text{NRD}$$

$$\frac{\text{Other R\&D Expenditures in Constant Dollars}}{\text{Real GNP}} = \text{ORD}$$

$$\gamma = f\left(\sum_{i=0}^{7} A_i \,(\text{NRD})_{-i},\ \sum_{i=0}^{7} A_i \,(\text{ORD}_{-i})\right)$$

The industry mix term is specified as follows:

$$IM_t = \sum_{i=1}^{N} \omega_{it} \left[\frac{(XIP_i)}{(XIP_m)} \right]_t$$

where:

IM_t = industry mix variable at time t

ω_{it} = average level of productivity (output/manhour) for each of i industries in the t^{th} year

XIP_{i_t} = index of industrial production for the i^{th} industry in year t, 1967 = 100.0

XIP_{m_t} = index of industrial production for the manufacturing sector in year t, 1967 = 100.0

Documentation supplied in the appendixes of the original study indicated that output was defined as constant dollar output for each two-digit SIC code industry estimated by the Chase Econometrics Long-Term Interindustry Service, as measured in the 1967 BEA Input-Output Table. Employment in each two-digit industrial classification was also used in lieu of manhours. In reestimating that part of the industry mix variable, we decided that a more precise measure of productivity would indeed be represented by output/manhour. Consequently, we used the same employment term but multiplied it by total annual average weekly hours worked. Hence ω_{it} =

$$\frac{(\text{Output in Constant }\$)_{it}}{(\text{Employment} * \text{Annual Average Weekly Hours})_{it}}$$

The ratio of $\frac{XIP_i}{XIP_m}$ was intended to measure the proportion of industry$_i$ in relation to the total manufacturing sector. This ratio does not measure that proportion; it is merely the ratio of two industrial production indexes at a single point in time. At best, when compared with its value in previous or successive periods, it may measure relative growth of an industry in relation to manufacturing as a whole; at worst, it explains nothing. In any case, a better measure of a shift in the relative contribution of industry i to the total industrial sector would be

$$\frac{\text{Output}_i}{\sum_{i=1}^{20} \text{Output}_i}$$

where the numerator represents output for industry i and the denominator total output for all of the industries being considered. The term itself was entered into the equation as the difference between the industry mix and its average over the estimation range (IMTOTAL - IMTOTALAVG).

In addition, we reestimated the old industry mix variable using the production indexes as outlined above. This mix variable is represented by AIMTOTAL.

3. Capacity Utilization Term

The last term incorporated in the 1976 equation was the difference between capacity utilization and its average over the range of estimation (CP - CPAVG). This variable was included as the major cyclical explanatory variable, using the rationale that an increase in R&D expenditures would have a greater impact on the economy during periods of slack employment than it would at cyclical peaks. Theoretically, productivity growth tends to be very low or even negative during periods of full employment and full capacity as shortages develop, labor efficiency declines, and older less efficient machines are used for production. Thus, adding additional expenditures to an already overheated economy would produce a smaller rate of return.

B. EQUATION ESTIMATION

The coefficients of the newly estimated equation for γ, Equation 10, is profoundly different from the equation estimated in the 1976 study; and the problems involved suggest this approach to the analysis may not provide sound results. Although capacity utilization remains the critical variable in the equation, the NASA R&D expenditures term as well as the other R&D expenditures term are insignificant. In addition, the industry mix term bears an intuitively unreasonable sign. The 1976 equation is shown as Equation 11 for purposes of comparison.

Equation 10

$$\text{GAMM1} = \underset{(0.22)}{0.115} + \underset{(0.06)}{0.004} * \text{NRD} + \underset{(1.14)}{0.029} * \text{ORD} - \underset{(-1.97)}{0.001} * (\text{IMTOTAL} - \text{IMAVG}) \underset{(-4.62)}{-0.136} * (\text{CP} - \text{CPAVG})$$

NOB	= 23 NOVAR = 5
RANGE	= 56 to 78
RSQ	= 0.835 CRSQ = 0.798 F(4/18) = 22.788
SER	= 0.3630 SSR = 2.372 DW(0) = 2.07
PCT SER	= 48.95 DEPENDENT MEAN = 0.74162

where

GAMM1	= γ Productivity Trend
NRD	= Constant Dollar NASA R&D Expenditures as a proportion of real GNP, using lag structure from Exhibit 17.
ORD	= Other Constant Dollar R&D Expenditures as a proportion of real GNP, using capacity utilization ratio.
IMTOTAL	= Industry mix variable.
IMAVG	= Mean of industry mix variable over range of estimation.
CP	= Capacity utilization.
CPAVG	= Mean of capacity utilization over range of estimation.

Equation 11

$$\gamma = -1.81 + \underset{(3.9)}{0.426}\ \text{NRD} + \underset{(2.0)}{0.474}\ \text{ORD}$$

$$+ \underset{(4.1)}{0.031}\ (\text{IM-IMAVG}) - \underset{(3.1)}{0.157}\ (\text{CP-CPAVG})$$

$R^2 = 0.883$
DW = 1.95
Sample Period = 1960-1974

There are two possible explanations can be offered for the severe deterioration in the specification.

- Use of a longer time series in the new analysis.
- Use of a different Υ series.

Each of these is discussed below.

1. Range of Estimation

The broader range of estimation, 1956-1978, as compared with 1960-1974. Reestimating over the 1960-1974 range results in a higher $\bar{R}^2$ of .912 and a significant coefficient on the ORD term; the coefficient on the industry mix term is insignificant and has an intuitively unreasonable sign. The coefficient on the NASA R&D term enters the equation with a negative sign and is insignificant (Equation 12).

<u>Equation 12</u>

$$\begin{aligned} \text{GAMM1} = & \underset{(-0.66)}{-0.474} + \underset{(-0.93)}{-0.051} * \text{NRD} + \underset{(1.89)}{0.060} * \text{ORD} - \\ & \underset{(-0.57)}{.006} * (\text{IMTOTAL} - \text{IMAVG}) \ \underset{(-2.55)}{-0.087} * (\text{CP} - \text{CPAVG}) \end{aligned}$$

NOB	=	15 NOVAR = 5
RANGE	=	60 to 74
RSQ	=	0.937 CRSQ = 0.912 F(4/10) = 37.269
SER	=	0.1907 SSR = 0.364 DW(0) = 2.27
PCT SER	=	30.58 DEPENDENT MEAN = 0.62357

Estimation over the 1960-1978 range also results in an unacceptable structure, as shown in Equation 13. The volatility of the coefficients over successive reestimation is ample evidence of the unstable structure of the equation, and the fact that the deterioration of the specification is not merely the result of the included additional observations.

<u>Equation 13</u>

```
GAMM1   = -0.769 + -0.022 * NRD + 0.069 * ORD -
          (-1.00)  (-0.52)        (1.98)

          0.001 * (IMTOTAL - IMAVG)  -0.078 * (CP - CPAVG)
          (-2.48)                    (-1.94)

NOB     = 19   NOVAR = 5
RANGE   = 60 to 78
RSQ     = 0.915   CRSQ = 0.890   F(4/14) = 37.469
SER     = 0.2352   SSR = 0.775   DW(0) = 2.19
PCT SER = 34.11   DEPENDENT MEAN = 0.68965
```

We also estimated an equation using our first derivative γ (GAMM2) instead of the percent change γ described in Phase I. Equation 14 represents the results, which are not significantly different from Equation 10.

Equation 14

$$\text{GAMM2} = \underset{(0.44)}{0.216} + \underset{(0.05)}{0.003} * \text{NRD} + \underset{(1.16)}{0.028} * \text{ORD} - \underset{(-2.09)}{0.001} * (\text{IMTOTAL} - \text{IMAVG}) \; \underset{(-4.49)}{-0.127} * (\text{CP} - \text{CPAVG})$$

NOB = 23 NOVAR = 5
RANGE = 56 to 78
RSQ = 0.831 CRSQ = 0.793 F(4/18) = 22.069
SER = 0.3493 SSR = 2.196 DW(0) = 2.03
PCT SER = 42.17 DEPENDENT MEAN = 0.82816

2. Historical Time Series for γ

The different historical time series for γ used in the current study may also account for a deterioration in the overall specification. Consequently, we reestimated the equation using the γ series from the 1976 Study. OLDGAMM1 represents the γ variable estimated in the 1976 Study.

Equation 15

$$\text{OLDGAMM1} = \underset{(1.05)}{1.442} \; \underset{(-2.53)}{-0.264} * \text{NRD} + \underset{(0.30)}{0.018} * \text{ORD} + \underset{(2.97)}{0.005} * (\text{IMTOTAL} - \text{IMAVG}) \; \underset{(-3.16)}{-0.206} * (\text{CP} - \text{CPAVG})$$

NOB = 15 NOVAR = 5
RANGE = 60 to 74
RSQ = 0.907 CRSQ = 0.870 F(4/10) = 24.457
SER = 0.3636 SSR = 1.322 DW(0) = 2.29
PCT SER = 38.90 DEPENDENT MEAN = 0.93467

Equation 16

```
OLDGAMM1 =   1.492  -0.184 * NRD + 0.009 * ORD +
             (2.12)  (-1.72)          (0.29)

           0.003 * (IMTOTAL - IMAVG)  -0.233 * (CP - CPAVG)
           (2.00)                     (-6.54)

NOB         19  NOVAR = 5
RANGE     = 56 to 74
RSQ       = 0.885   CRSQ = 0.852   F(4/14) = 26.929
SER       = 0.4022   SSR = 2.265   DW(0) = 1.93
PCT SER   = 39.61   DEPENDENT MEAN = 1.01526
```

Equations 15 and 16 provide significant evidence that the deterioration in the specification is not the result of the different historical time series for γ. Since the current study uses a different industry mix variable, we substituted the industry mix variable which was estimated using the methodology outlined in the 1976 study. The results, shown in Equations 17 and 18, are similar to Equations 15 and 16.

Equation 17

```
OLDGAMM1 =   2.466  -0.188 * NRD  -0.035 * ORD +
             (2.90)  (-2.21)         (-1.02)

   0.003 * (AIMTOTAL - AIMTOTALAVG)  -0.275 * (CP - CPAVG)
   (2.72)                            (-6.93)

NOB       = 19   NOVAR = 5
RANGE     = 56 to 74
RSQ       = 0.903   CRSQ = 0.876   F(4/14) = 32.705
SER       = 0.3687   SSR = 1.903   DW(0) = 2.16
PCT SER   = 36.32   DEPENDENT MEAN = 1.01526
```

Equation 18

```
OLDGAMM1 =   1.128  -0.245 * NRD + 0.028 * ORD +
             (0.86)  (-2.60)        (0.48)

  0.004 * (AIMTOTAL - AIMTOTALAVG)  -0.208 * (CP - CPAVG)
  (3.14)                            (-3.28)

NOB      =  15   NOVAR = 5
RANGE    =  60 to 74
RSQ      =  0.912   CRSQ = 0.877   F(4/10) = 25.996
SER      =  0.3537   SSR = 1.251   DW(0) = 2.21
PCT SER  =  37.84   DEPENDENT MEAN = 0.93467
```

Given the evidence provided by Equations 17 and 18 (which do not suffer from any of the data problems outlined in Phase I since the historical time series for γ is identical to the series used in 1976), we cannot reach the same conclusions outlined in the original study or validate its results.